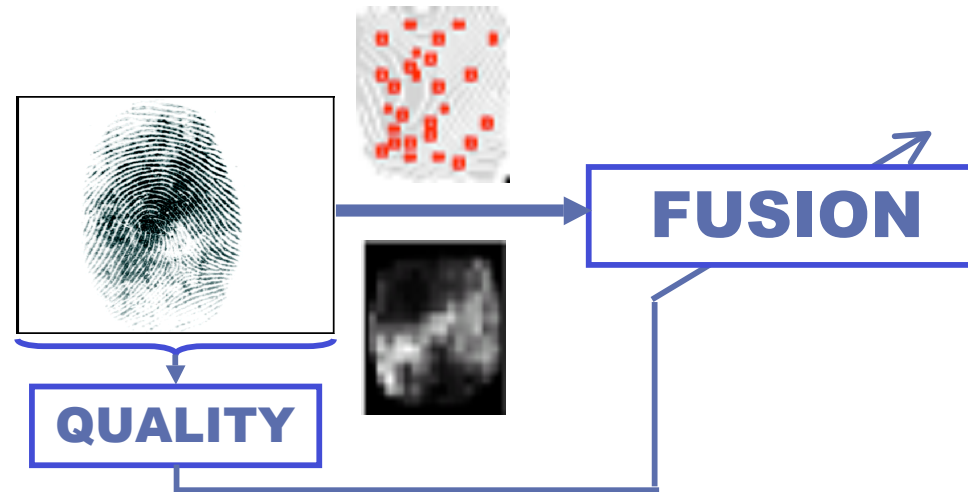


# Incorporating Biometric Quality In Multi-Biometrics



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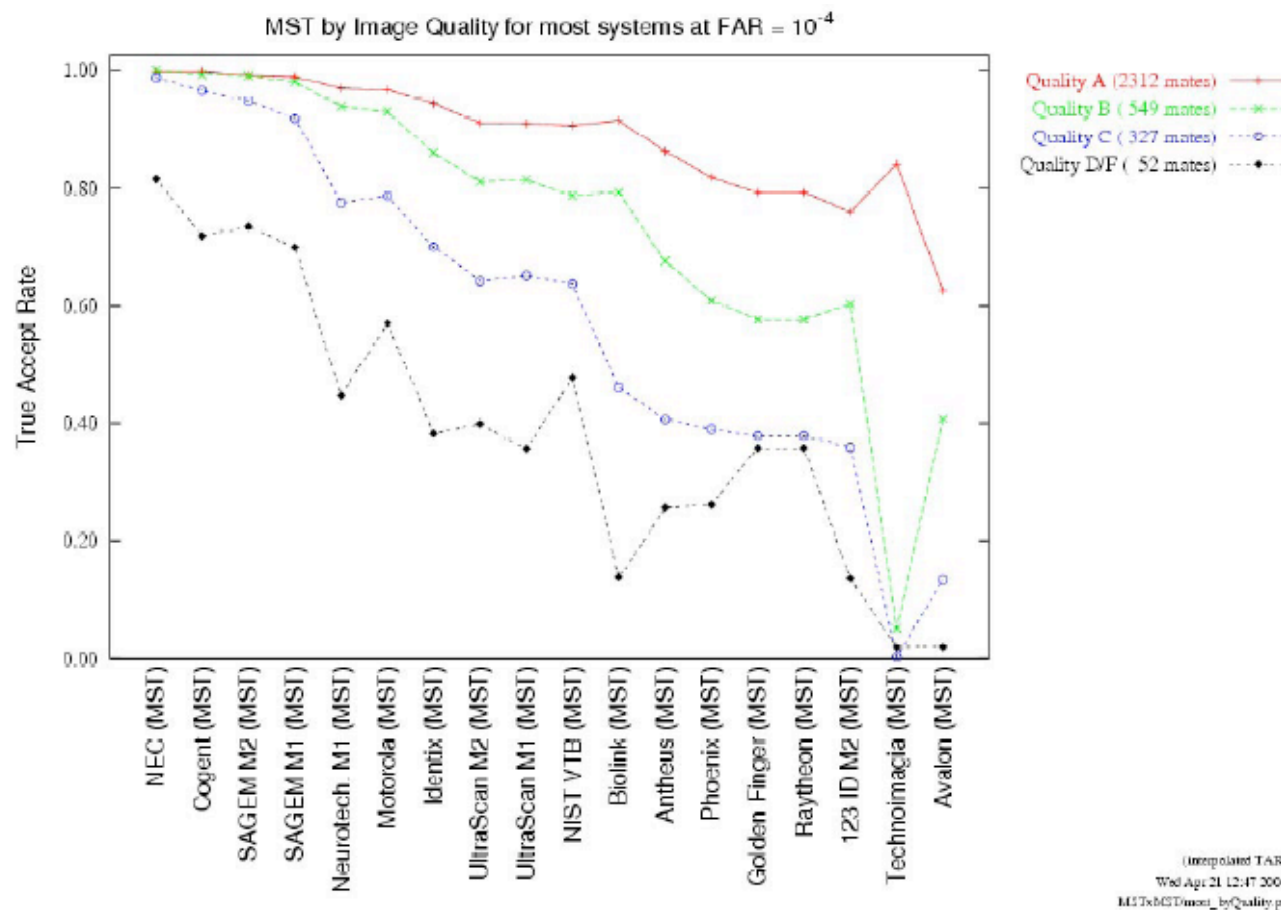
# Outline

- **Motivation**
- **Image Quality: The FVC Experience**
- **FVC2004: Multi-Algorithm Fingerprint Verification**
- **Quality-Based Fusion**
  - **Experimental Setup**
  - **Results**
- **Conclusions**



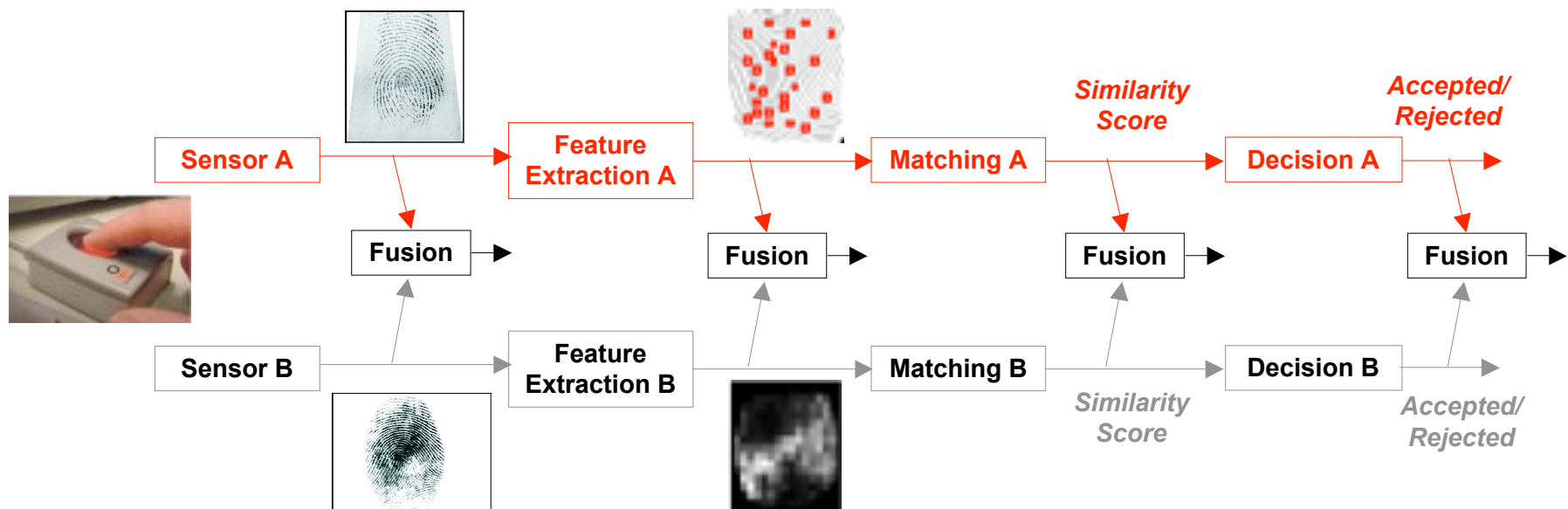
# Motivation (I)

- Image quality:
  - Performance drop under degraded image quality.
  - Big interest in characterizing this degradation, (e.g., NIST FpVTE 2003, FVC2004, BQW)



## Motivation (II)

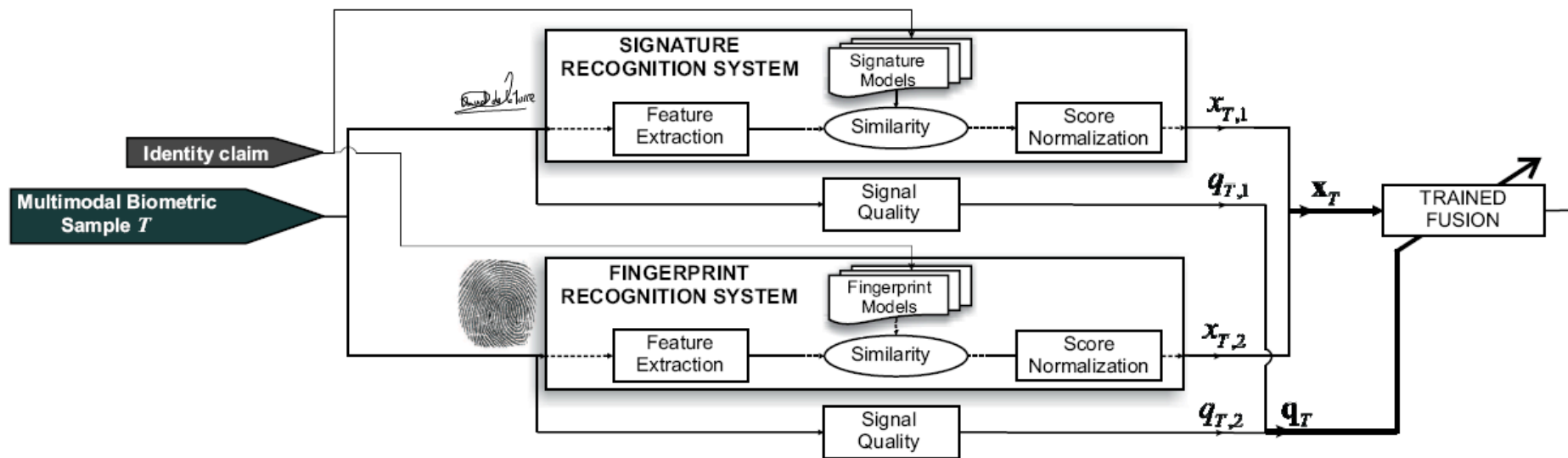
- Multi-algorithm fingerprint recognition:
  - A number of works have shown the benefits of combining multiple approaches for fingerprint recognition.
  - Different levels of combination: sensor-level, feature-level, score-level, decision-level.



*We focus on **score-level fusion**.*

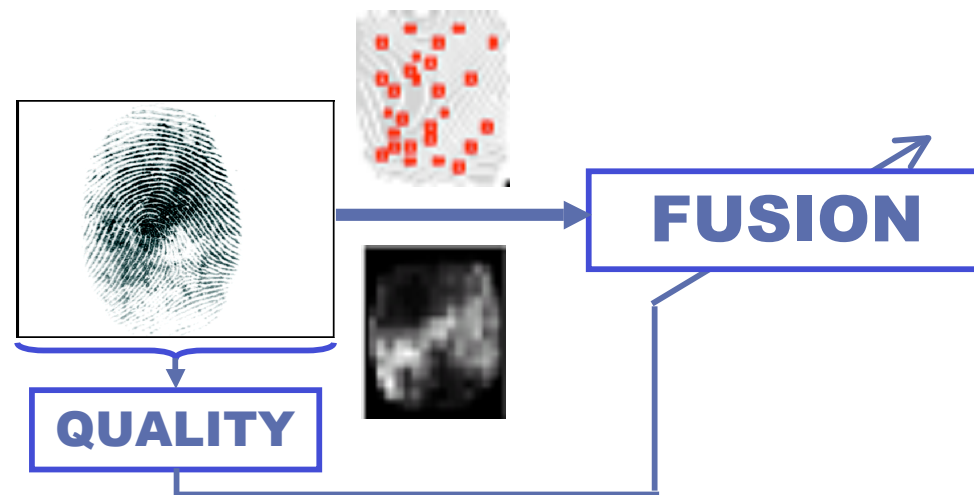
## Motivation (III)

- Quality-based multimodal biometrics:
  - Recent works have shown the benefits of incorporating biometric quality when combining different biometric traits.
  - System model for score-level quality-based fusion:



***Quality-based multi-algorithm fingerprint verification***

# Image Quality: The FVC2004 Experience



J. Fierrez-Aguilar, L. Nanni, J. Ortega-Garcia, R. Cappelli and D. Maltoni, "Combining multiple matchers for fingerprint verification: a case study in FVC2004", *Lecture Notes in Computer Science* 3617: 1035-1042, 2005.

# Fingerprint Technology Evaluations

- Recent fingerprint technology evaluations:
  - Fingerprint Vendor Technology Evaluation (FpVTE2003)
    - Organized by NIST.
  - Fingerprint Verification Competitions (FVC2000, 2002, 2004)
    - Organized by BioLab (University of Bologna), National Biometric Test Center (San Jose State Univ.) and PRIP Lab. (Michigan State Univ.).

*We focus on **Fingerprint Verification Competition 2004.***





## FVC2004: Data

- Fingerprint data: 100 fingers x 8 impressions x 4 sensors
- Different DBs correspond to different fingers.
- Image quality is low to medium due to exaggerated plastic distortions, and artificial dryness and moistness.



**DB1**

Optical

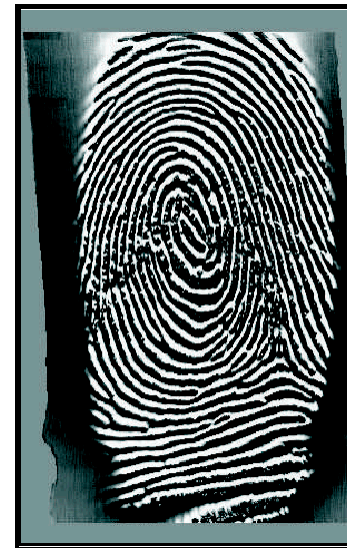
*CrossMatch V300*



**DB2**

Optical

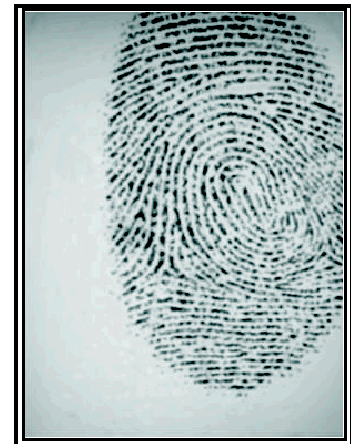
*DP UareU4000*



**DB3**

Thermal

*Atmel FingerChip*



**DB4**

Synthetic

*SFinGe v3.0*



# FVC2004: Participants

■ Open (41 algorithms) and light (26 algorithms) sub-competitions.

Participant	Preprocessing		Alignment		Features								Matching				
	Segmentation	Enhancement	Before Matching, During matching	Displacement, Rotation, Scale, Non-linear	Minutiae	Singular points	Ridges	Ridge counts	Orientation field	Local ridge frequency	Texture measures	Image parts	Minutiae (global)	Minutiae (local)	Ridge pattern (geometry)	Ridge pattern (texture)	Correlation
002	✓	✓	D	NL	✓				✓				✓	✓			
009	✓	✓	BD	DRS	✓	✓	✓	✓	✓	✓			✓				
016		✓			✓		✓						✓				✓
026				DR	✓			✓	✓				✓				
027	✓	✓	D	DRS							✓					✓	✓
039	✓	✓	D	N	✓				✓	✓			✓				
041	✓	✓	D	DR	✓		✓								✓		
047	✓		D	DRSN	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	

Description of FVC2004 submissions, as provided by the participants, following the taxonomy proposed in:

D. Maltoni, D. Maio, A. K. Jain, S. Prabhakar,  
*Handbook of Fingerprint Recognition*, Springer, 2003.

■ Details in <http://bias.csr.unibo.it/fvc2004/> including pointers to the identities of non-anonymous participants, individual results, and comparative charts.

## FVC2004: Performance Evaluation

■ Experimental protocol (for each DB):

- Genuine:  $(100 \times 8 \times 7) / 2 = 2800$  genuine matching scores
- Impostor:  $(100 \times 99) / 2 = 4950$  impostor matching scores

■ All matching scores in the  $[0,1]$  range.

■ A comprehensive set of performance indicators is reported: score histograms, verification error rates at different operational points, computing time, memory allocated, and others.

■ We focus on the **open** sub-competition, with the **EER** as the indicator for the experimental comparisons.

■ Details in <http://bias.csr.unibo.it/fvc2004/> and

R. Cappelli, D. Maio, D. Maltoni, J.L. Wayman, A.K. Jain, "Performance Evaluation of Fingerprint Verification Systems", *IEEE Trans. PAMI*, Jan 2006.

## **FVC2004: Results**

■ FVC2000 (natural acquisition, 11 algorithms):

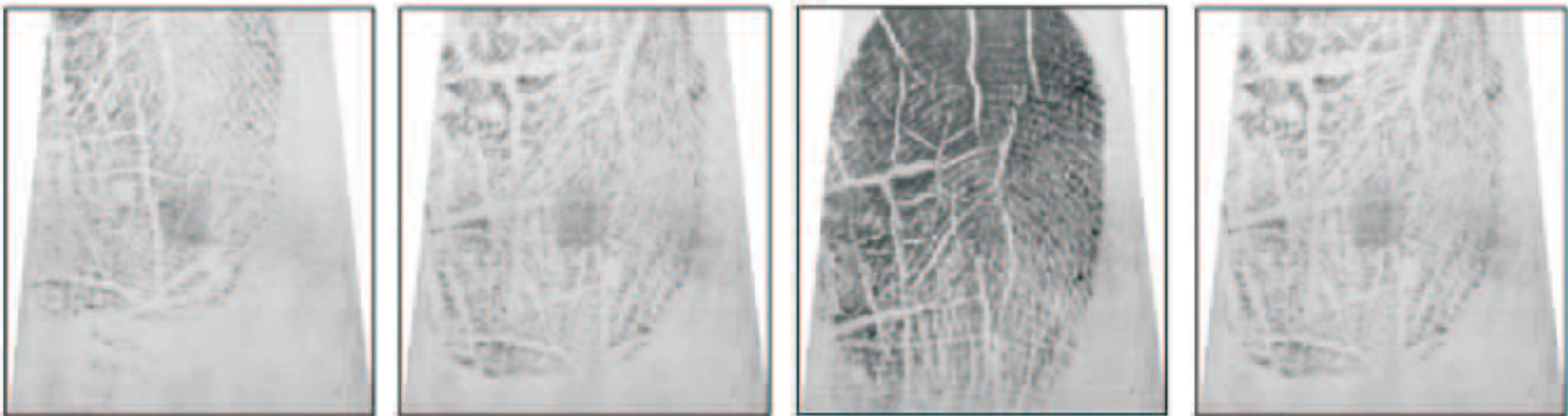
- Winner 1.73% EER, average of first 5 systems 4.52% EER.

■ FVC2002 (natural acquisition, 31 algorithms):

- Winner 0.19% EER, average of first 5 systems 0.52% EER.

■ FVC2004 (exaggerated distortion, 41 algorithms):

- Winner 2.07% EER, average of first 5 systems 2.36% EER.



# FVC2006: Announcement



■ Some changes with respect to previous editions:

- DATA: Larger DBs, 150 fingers, 12 impressions per finger.
- DATA: Most difficult fingers from a larger pool of fingers (NFIQ).
- PLANNED STUDIES: Interoperability, Quality.

## **IMPORTANT DATES:**

Participant registration deadline:	June 30, 2006
Development databases available online:	July 1, 2006
Algorithm submission deadline:	October 31, 2006
Expected publication of the results:	January, 2007

For further information, please visit: <http://bias.csr.unibo.it/fvc2006>  
or send an e-mail to: [fvc2006@csr.unibo.it](mailto:fvc2006@csr.unibo.it)

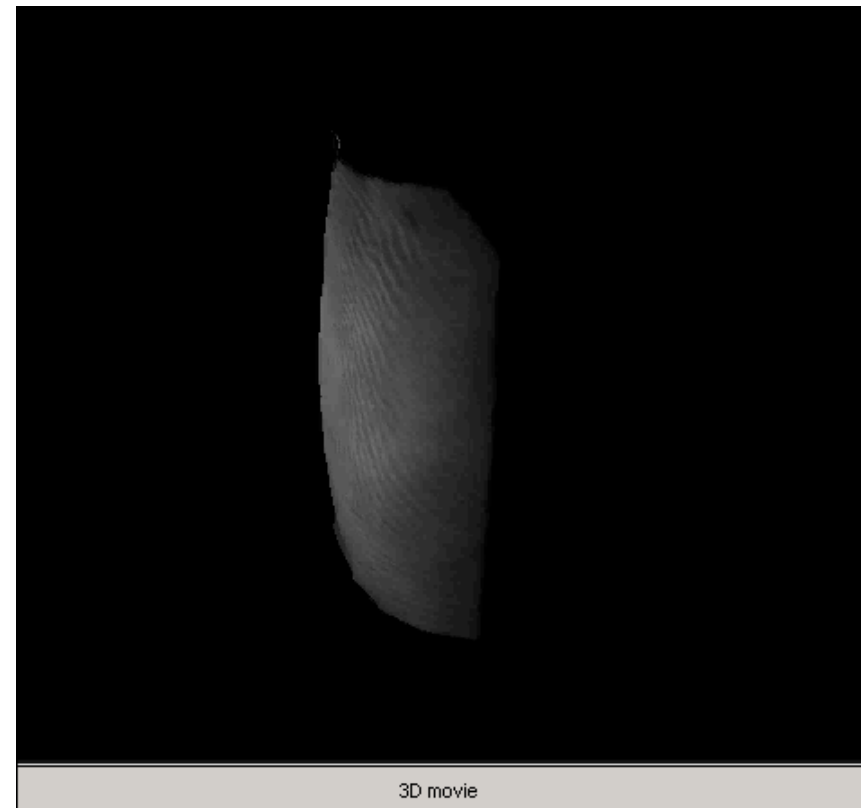
# How to Overcome Low Quality Images?

## New sensors:

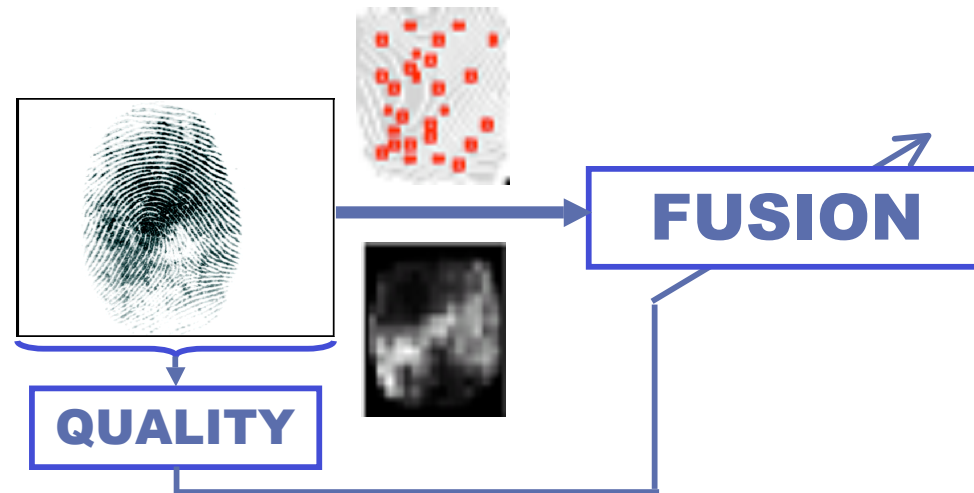
- Multi-Spectral Imaging.
- Touch-less Biometric Sensors (TBS):



## Multi-algorithm fusion.



# FVC2004: Multi-Algorithm Fingerprint Verification



J. Fierrez-Aguilar, L. Nanni, J. Ortega-Garcia, R. Cappelli and D. Maltoni, "Combining multiple matchers for fingerprint verification: a case study in FVC2004", *Lecture Notes in Computer Science* 3617: 1035-1042, 2005.

## **FVC2004: Multi-Algorithm Fusion**

- Performance improves with the fusion of up to 7 systems.
- Performance deteriorates when combining more than 10 systems.
- The largest improvement is obtained for the fusion of 2-3 systems.



# FVC2004: Multi-Algorithm Fusion

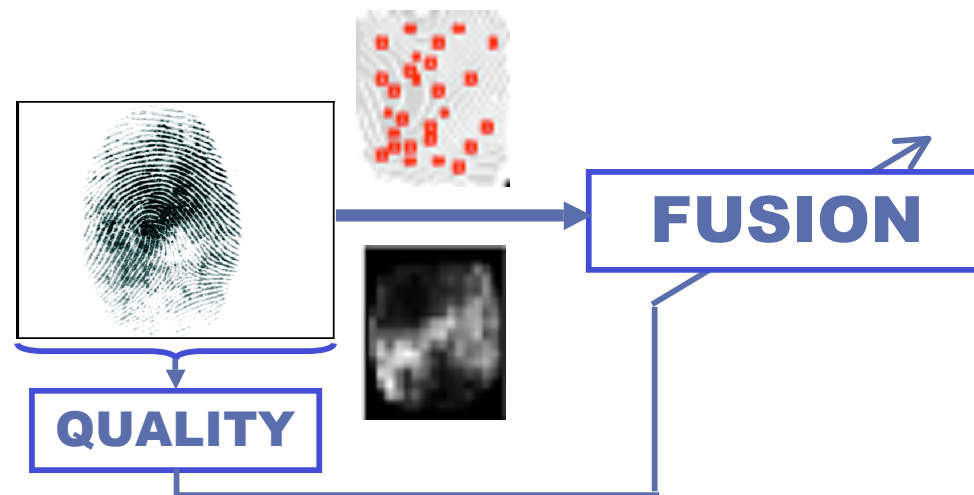
Some interesting examples:

DB1				DB2				DB3				DB4			
<i>Participant</i>	Ranking on DB1 (EER)	EER on DB1	EER on DB1 (Sum)	<i>Participant</i>	Ranking on DB2 (EER)	EER on DB2	EER on DB2 (Sum)	<i>Participant</i>	Ranking on DB3 (EER)	EER on DB3	EER on DB3 (Sum)	<i>Participant</i>	Ranking on DB4 (EER)	EER on DB4	EER on DB4 (Sum)
047	1st	1.97		039	1st	1.58		047	1st	1.18		071	1st	0.61	
047	1st	1.97	1.45	039	1st	1.58	0.92	101	2nd	1.20	0.28	071	1st	0.61	0.48
101	2nd	2.72		101	7th	3.56		075	5th	1.85		101	2nd	0.80	
047	1st	1.97	1.20	039	1st	1.58	0.73	101	2nd	1.20	0.23	071	1st	0.61	0.39
101	2nd	2.72		101	7th	3.56		075	5th	1.85		101	2nd	0.80	
004	6th	4.10		103	14th	4.99		078	29th	7.56		113	12th	1.98	
047	1st	1.97	1.17	039	1st	1.58	0.67	101	2nd	1.20	0.21	071	1st	0.61	0.31
101	2nd	2.72		004	3rd	2.79		075	5th	1.85		101	2nd	0.80	
004	6th	4.10		101	7th	3.56		004	6th	1.89		039	4th	1.07	
052	19th	8.41		103	14th	4.99		002	13th	3.82		075	31th	5.99	

Matching Strategy  
Based on:

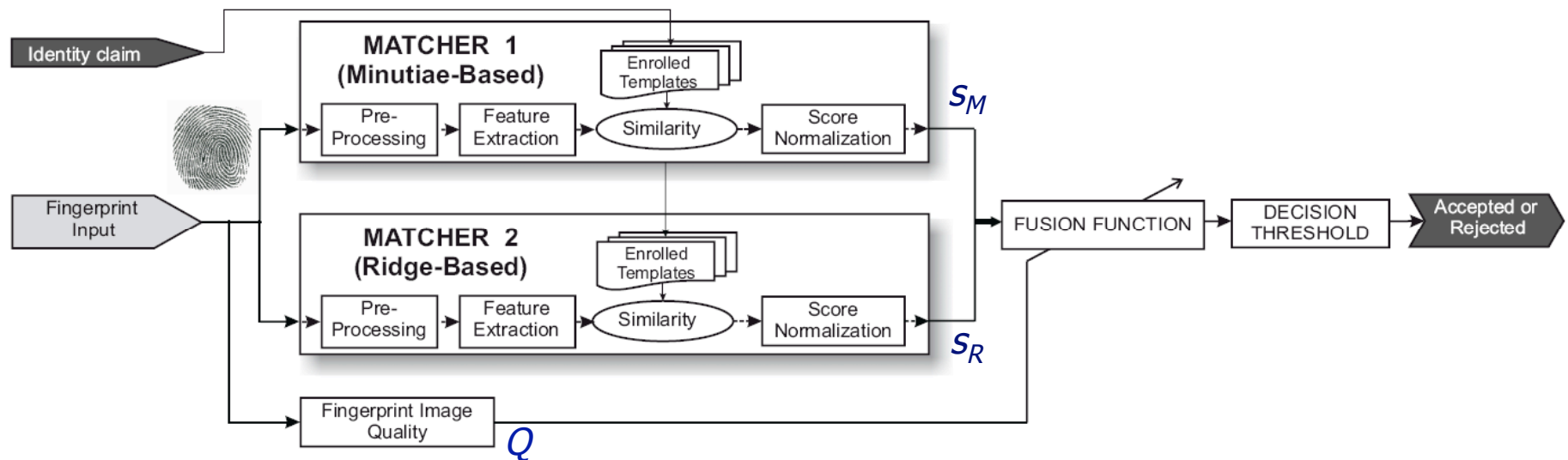
- Ridge correlation
- Minutiae Local
- Minutiae Global

## Quality-Based Fusion



J. Fierrez-Aguilar, Y. Chen, J. Ortega-Garcia and A. K. Jain, "Incorporating image quality in multi-algorithm fingerprint verification", *Lecture Notes in Computer Science* 3832:213-220, 2006.

# System Architecture



## Assumptions:

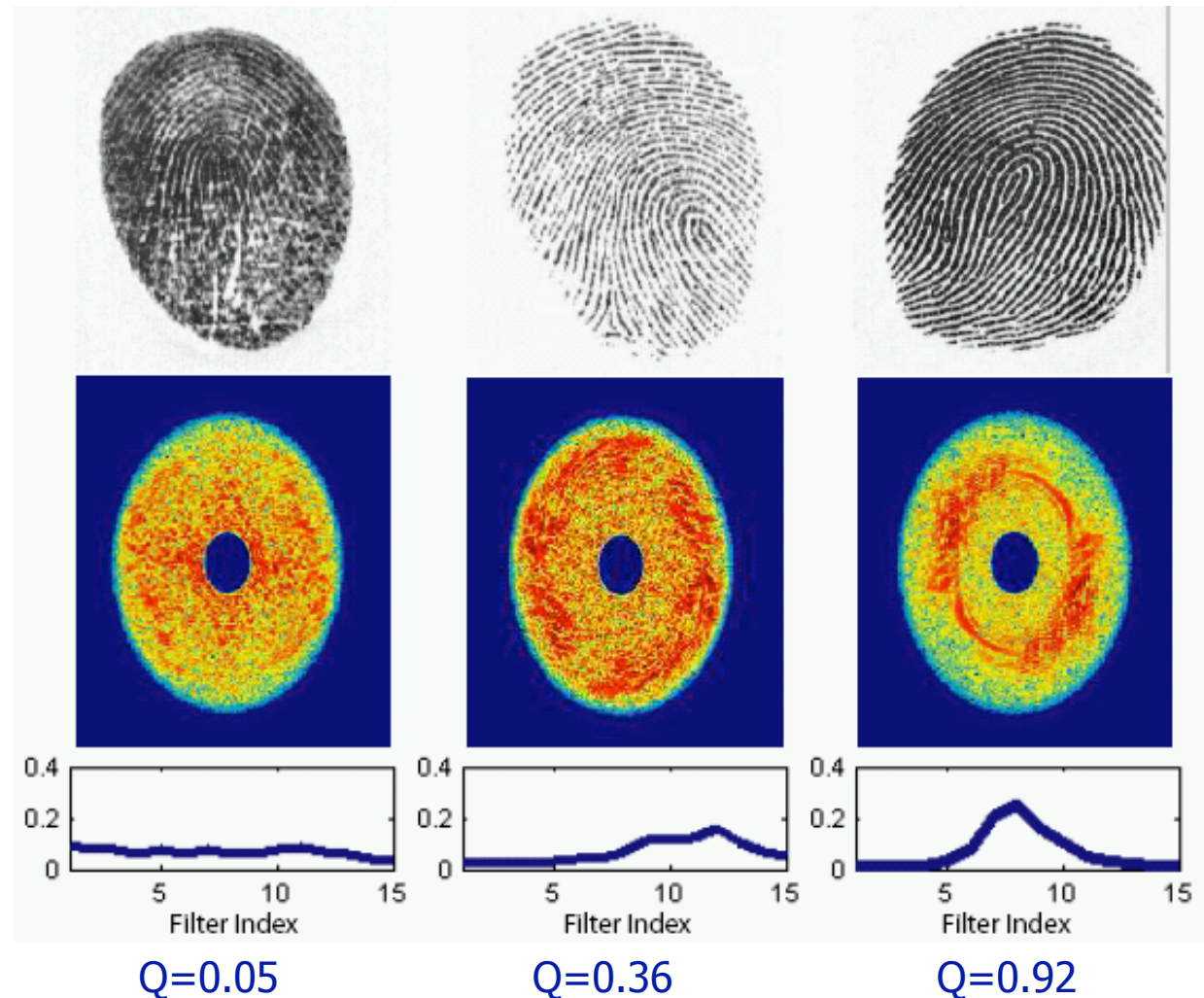
- Matching scores  $s_M$  and  $s_R$  are already normalized to the range  $[0,1]$ .
- Performance of one matcher (minutiae) drops significantly as compared to the other one under image quality degradation.

$$\rightarrow s_Q = \frac{Q}{2} s_M + \left(1 - \frac{Q}{2}\right) s_R$$

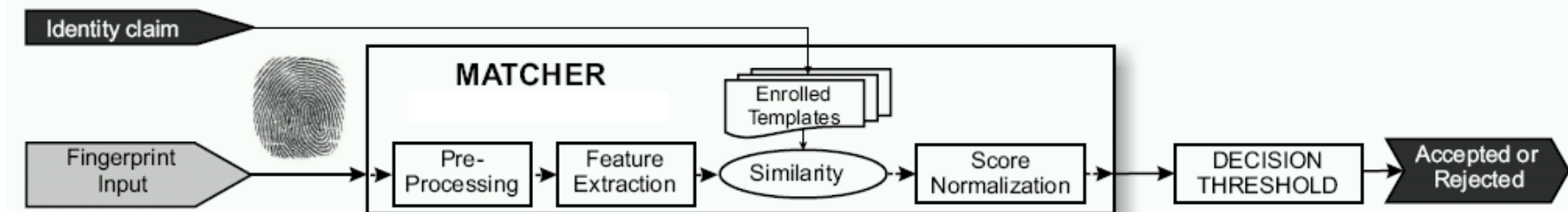
NOTE: For more general formulations ( $n$  matchers) using Bayesian theory and SVMs see Bigun *et al.* (ICIAP 2003) and Fierrez-Aguilar *et al.* (PR 2005), respectively.

# Automatic Fingerprint Quality Assessment

- Based on global features:
  - A global measure of quality is computed for each image.
  - The quality is related to the energy concentration in ring-shaped regions of the power spectrum.



# Minutiae-Based Matcher



## PREPROCESSING

A grayscale fingerprint image showing the initial state before preprocessing.

- Normalization
- Orientation field
- ROI
- Ridge extraction & profiling

## SIMILARITY

Two grayscale fingerprint images side-by-side, showing the process of comparing their minutiae patterns.

- Minutiae alignment
- Pattern matching (edit distance)

## FEATURE EXTRACTION

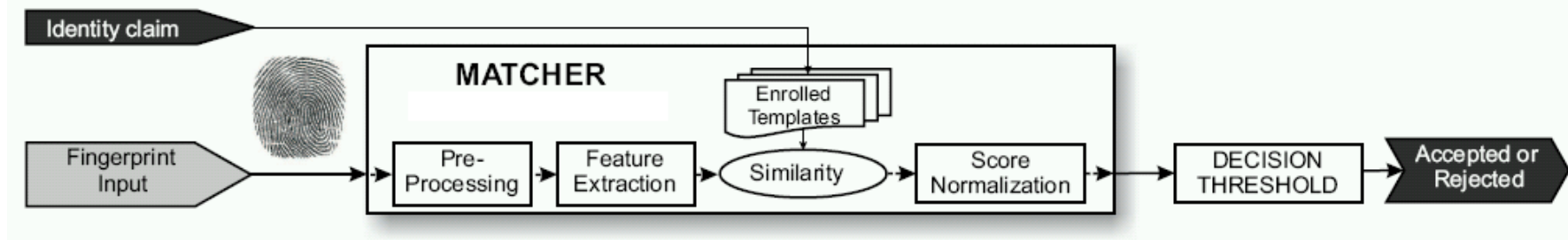
A grayscale fingerprint image showing the result of feature extraction, with ridges clearly defined.

- Thinning
- Imperfection removal
- Minutiae extraction

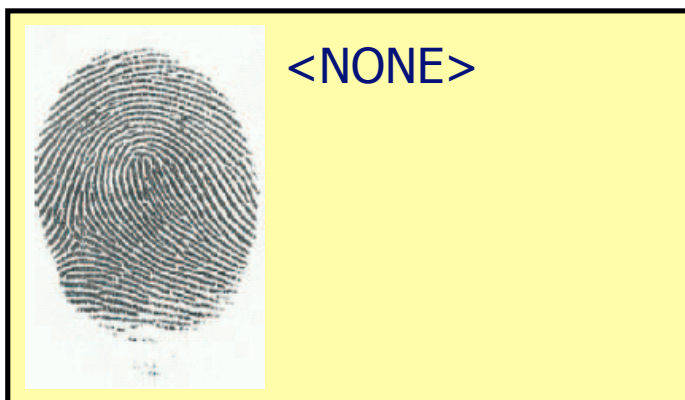
D. Simon-Zorita, J. Ortega-Garcia, J. Fierrez-Aguilar, J. Gonzalez-Rodriguez, "Image quality and position variability assessment in minutiae-based fingerprint verification", *IEE Proc. VISIP*, vol. 150, no. 6, pp. 402-408, 2003.



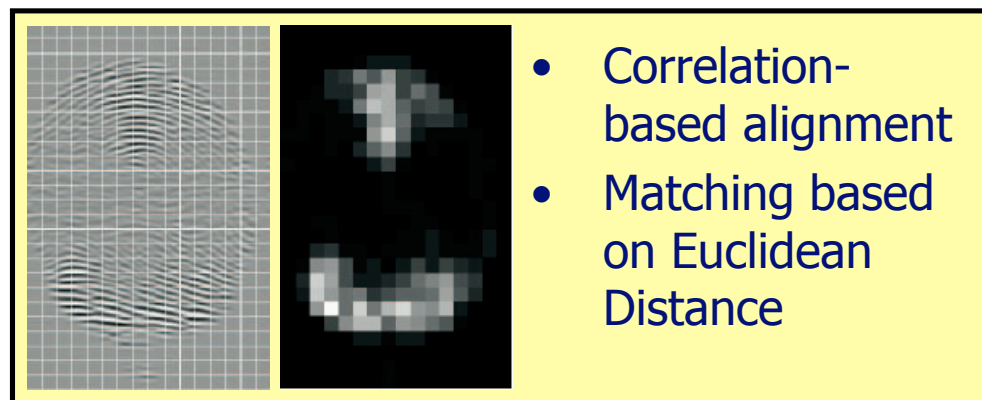
# Ridge-Based Matcher



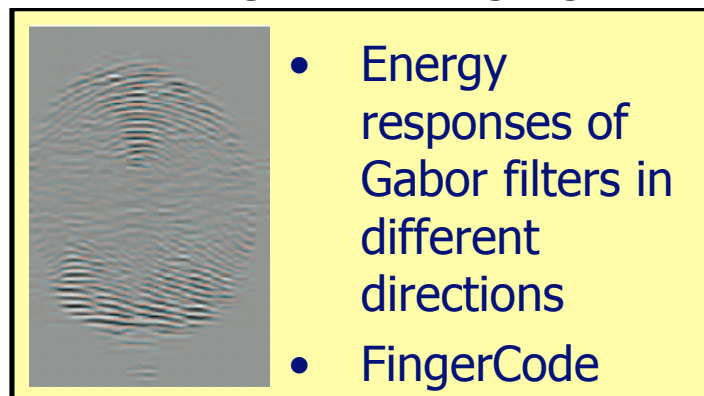
## PREPROCESSING



## SIMILARITY



## FEATURE EXTRACTION



A. Ross, J. Reisman, A. K. Jain, "Fingerprint matching using feature space correlation", Proc. BioAW, Springer LNCS, vol. 2359, pp. 48-57, 2002.

## Database: MCYT

- Scanner: UareU from Digital Persona.
- Fingerprint image: 500dpi, 400 x 256 pixels.
- Fingerprint corpus: 750 fingers (75 subjects) x 10 impressions.



J. Ortega-Garcia,  
J. Fierrez-Aguilar, *et al.*,  
"MCYT baseline corpus:  
A bimodal biometric  
database", *IEEE Proc. VISP*,  
vol. 150, no. 6, pp. 395-  
401, 2003.



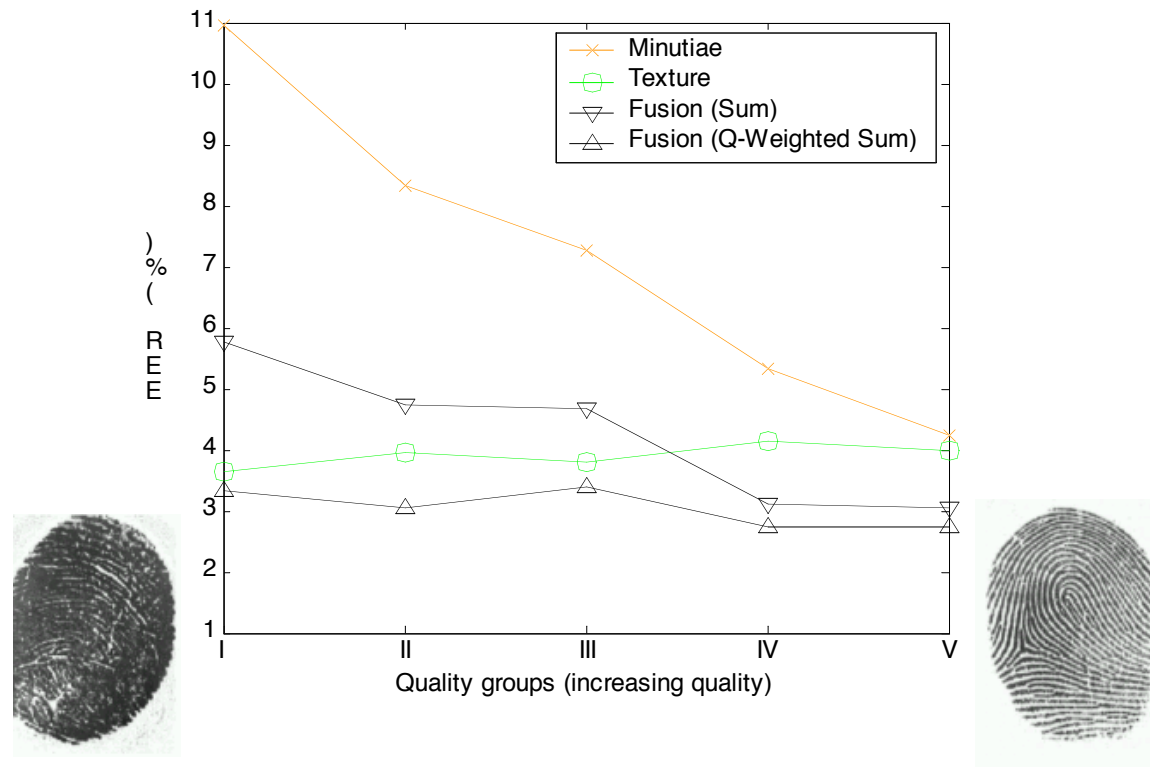
## Experimental Protocol

- Enroll: one impression of each finger.
- Genuine matchings: remaining 9 impressions (9 x 750 trials).
- Impostor matchings: 1 impression from all the remaining fingers (750 x 749 trials)
- All fingers are classified into 5 equal-sized disjoint quality groups, based on a quality ranking.
- The quality ranking is based on the average quality of the genuine matchings corresponding to each finger:

$$Q_{matching} = \sqrt{Q_{enrolled} \cdot Q_{test}}$$

where  $Q_{enrolled}$  and  $Q_{test}$  are global image quality measures.

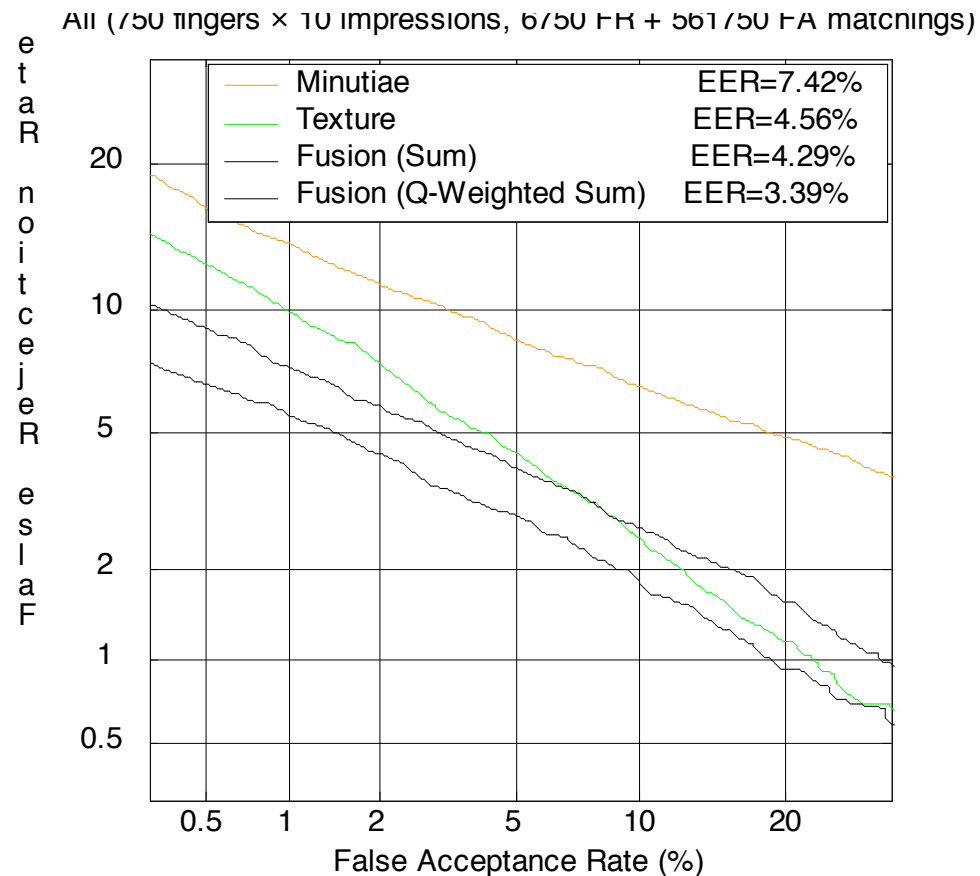
# Performance Comparison for Quality Groups



## Observations:

- The performance of the **minutia-based** matcher drops significantly under degraded image quality.
- The performance of the **ridge-based** matcher is robust to the global image quality measure considered.
- Sum fusion outperforms the best system only for good quality images.
- *Quality-based fusion* outperforms the best system in all cases.

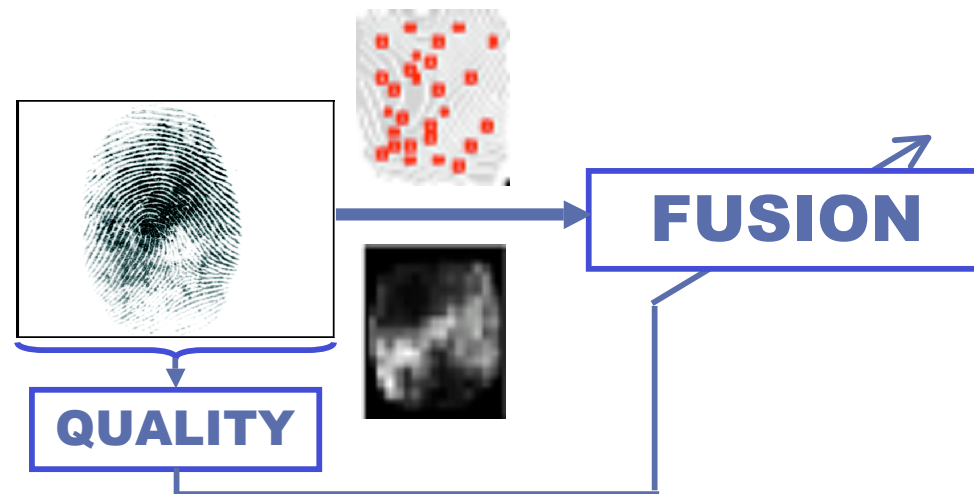
# Fusion Results



## Observations:

- Due to large differences in performance between the two systems, sum fusion improves the performance only in a region of the DET curve.
- Incorporating the image quality in the sum fusion leads to improved performance in all cases.

# Conclusions



## Conclusions (I)

- Large performance drop in FVC2004 with respect to previous editions due to image quality (exaggerated distortion).
- This can be overcome by multi-algorithm fusion (reduced number of heterogeneous systems).
- Multi-algorithm fusion can be further improved by incorporating image quality:
  - Quality-based fusion of **ridge-** and **minutiae-based** matchers.
  - Global quality measure based on power spectrum.
  - Large corpus comprising 7500 images from 750 fingers.

## Conclusions (II)

- Experimental findings:
  - The **ridge-based** approach outperforms the **minutiae-based** approach in low quality image conditions.
  - Both approaches obtain similar performance in good quality conditions.
  - The **ridge-based** approach is robust to quality image degradation (almost independent of image quality) while the **minutiae-based** approach experiments a large performance drop.
  - Quality-based fusion overcomes the problem of performance drop of one component in multi-algorithm fingerprint verification.



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